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Characteristics of sea turtles incidentally captured in the U.S. Atlantic sea scallop dredge fishery

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ABSTRACT

Interactions between sea turtles and sea scallop dredges are an important conservation issue. In this paper, we present information which can be used to inform bycatch mitigation strategies. We collected samples and data from turtles observed in the U.S. commercial scallop dredge fishery and examined interactions and injuries, genetic samples, and turtle size. Observers documented injuries in about two-thirds (52 of 74) of the live and fresh dead turtles. When the location of the turtle in the gear was described, it was most frequently reported in the dredge ($n = 19$), in the bag ($n = 9$), or on top of the catch ($n = 7$). Although several different injury and interaction scenarios were described by observers, the most common was an injured turtle, caught in the dredge, and brought aboard the fishing vessel. The timing of injuries was often unknown, but when observer comments provided information about timing, most injuries likely occurred before the turtle was brought aboard the vessel. The majority of turtles observed in the scallop dredge fishery were juvenile loggerheads. Mixed stock analysis using genetic data, suggested that most loggerheads captured in the scallop fisheries are from the south Florida nesting population, however there was a high level of uncertainty in these estimates.

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1. Introduction

Interactions between threatened and endangered sea turtles and Atlantic sea scallop (*Placopecten magellanicus*) dredge gear (Fig. 1) are an important conservation issue. The National Marine Fisheries Service (NMFS) estimates that hundreds of turtles have been captured and injured in the scallop dredge fishery (Murray, 2004a,b, 2005). The NMFS and the scallop industry are researching ways to modify scallop dredge gear to reduce turtle injuries (DuPaul et al., 2004; Smolowitz et al., 2005; Haas et al., 2006; Smolowitz, 2006). NMFS must continue to investigate and implement additional gear modifications to reduce the severity of the interactions between turtles and scallop dredge gear (NMFS, 2008). There are few small-scale examinations of the turtle interactions with scallop dredge gear (DuPaul et al., 2004; Smolowitz et al., 2005) but a comprehensive examination is needed to develop gear designs which reduce turtle bycatch and to measure the effect of these interactions on the status of turtle populations.

In order to design and evaluate gear modifications which reduce turtle injuries, information is needed on the size of turtles and types of interactions and injuries that have been observed in the scallop dredge fishery. Turtle size information can be used by gear researchers when evaluating the distance between hard parts of the dredge (such as the spacing of the bale support bars or the configuration of turtle excluder devices). Information on the types of interactions and injuries can be used to focus gear modifications on the parts of the dredge that that are associated with most turtle interactions and injuries.

The Endangered Species Act requires NMFS to determine whether federal fisheries result in reductions in reproduction, numbers or distribution of turtles. The turtle species most commonly documented as bycatch in the scallop fishery is the threatened loggerhead (*Carretta caretta*, Murray, 2004a,b, 2005). Loggerheads originate from a variety of nesting beaches, including the United States (northeast Florida to North Carolina, south Florida, northwest Florida, Dry Tortugas), Mexico, Greece, Turkey and Brazil (Bass et al., 2004; Bowen et al., 2004; Bolten et al., 1998; Encalada et al., 1998), but information on the nesting beach origins of turtle bycatch in the scallop dredge fishery is currently missing. Summaries of size class and loggerhead stock composition of turtles captured in the scallop fishery would allow better assessment of the effects of the scallop fishery on loggerhead nesting groups.

In this paper, we present and analyze information collected from turtles incidentally captured in the scallop dredge fishery.

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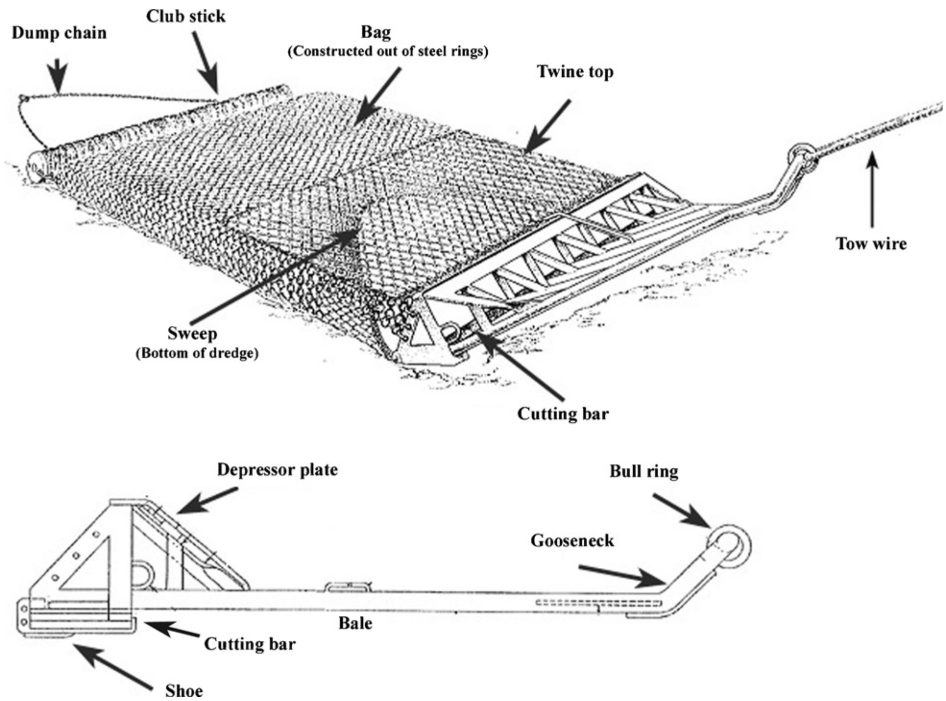

Fig. 1. Anatomy of a standard scallop dredge. The top drawing is of a scallop dredge frame and bag together. The bottom drawing is of scallop dredge frame only.

We report the number of turtles associated with various parts of the dredge and summarize the types of injuries associated with different types of interactions. We evaluate the nesting beach origin (based on tissue samples) and describe the size-classes of the captured turtles.

2. Methods

The data analyzed were obtained from the NMFS Northeast Fishery Observer Program (NEFOP), which assigns observers to commercial fishing vessels. We used the term "capture" to describe all turtle-gear interactions recorded by NMFS NEFOP observers in the scallop fishery even though turtles were not always physically captured. Observers were instructed to identify the species, photograph identifying characteristics and injuries, describe new and old injuries, obtain three body measurements, look for flipper and PIT (passive integrated transponder) tags, apply flipper tags (if appropriate), collect tissue samples for genetic analysis, draw diagrams of turtles, assess the condition of the turtle, and write a description of the animal and gear interaction. We evaluated all available information for each turtle capture and created categorical variables to describe injuries and interactions. We examined the electronic observer records, copies of original data logs, observer comments in the incidental take logs and haul logs, diagrams, photographs, notes on the trip data, and notes from interviews with observers. The information we reviewed far exceeded that reported in Smolowitz et al. (2005) because we had access to more data sources.

The size, injury, and interaction analyses within this paper were based on 74 turtles that were reported observed from 1996 to 2005 in association with scallop dredge gear. Some of the turtles were captured in a dredge equipped with rock chains, but none were captured in a dredge equipped with chain mats even though dredges with chain mats were observed in 2004 (Murray, 2005). Most of the captured turtles were observed in the summer and fall in the Mid-Atlantic region (Fig. 2). The earliest observed capture occurred on 17 June, and the latest occurred on 21 October. In general, observer coverage was higher and observer comments were more extensive in the later years (especially 2003 and 2004, see Murray, 2004a,b, 2005 for more details).

In addition to the 74 turtles in this analysis, observers reported 9 turtles as moderately or severely decomposed. We excluded these decomposed turtles because their decomposition suggested they died before interacting with the observed dredge gear. Six of the decomposed turtles were tangled in gillnet gear and were captured on the same trip in two non-consecutive hauls. We included turtle captures in both on-watch (when an observer is on duty and systematically collecting data) and off-watch hauls (when an observer is off duty, but may opportunistically collect data).

2.1. Injuries

We based our injury determinations on all available information. We defined an injured turtle as a fresh-dead or live turtle with any

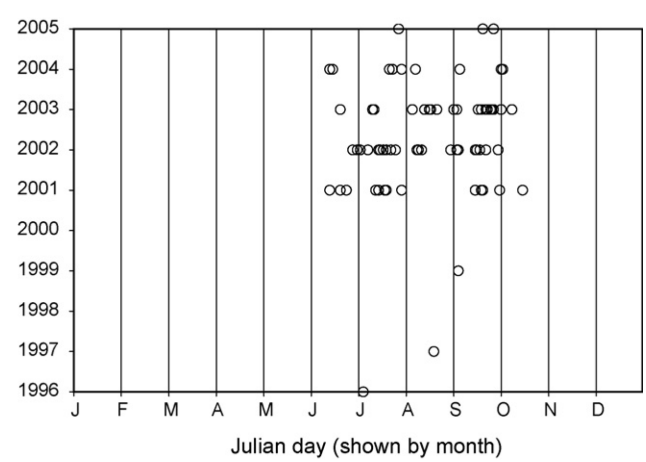

Fig. 2. Year and Julian day of observed turtle bycatch in the scallop dredge fishery. Vertical grid-lines represent the first day of each month. Moderately and severely decomposed turtles not included.

unhealed injury that was observed in the field or via photograph. This included animals exhibiting any abrasion, scrape, crack, cut, exposed tissue, bleeding, buoyancy problem, body discoloration, and turtles that appeared comatose (even if they were resuscitated).

We created a categorical uncertainty variable (UNC) to quantify the amount of uncertainty in the injury determinations. A turtle was assigned the highest uncertainty level (UNC = Highest) if an observer said the condition of the turtle was unknown, did not report seeing injuries but the turtle was not brought aboard for inspection (or brought aboard but not seen by observer), provided comments or other evidence to suggest the injuries might not have been fresh, or provided comments that were so vague or inconsistent that a reasonable injury assessment could not be made. The intermediate uncertainty level (UNC = Intermediate) was assigned if the observer did not explicitly state whether they examined the turtle for injuries when the turtle was brought aboard and no injuries were noted, stated the injury was healed but provided no information to support this conclusion, or did not document some of the injuries. This category also included cases where the observer used ambiguous phrases (such as "appeared uninjured" and "apparently unharmed") with no supporting details to describe the animal condition or the extent that the turtle was examined. The lowest uncertainty level (UNC = Lowest) was assigned if an injury was clearly reported (via photograph, sketch, or text) or if the observer explicitly stated they examined the turtle for injuries (while the turtle was aboard the vessel). In some of the analyses, records with high uncertainty (UNC = Highest) were excluded from the dataset. Filtering records by level of uncertainty reflected the observers' level of interaction with the turtle more effectively than simply using on-watch and off-watch haul information.

The uncertainty variable (UNC) was used to explore but not eliminate a potential bias in the data. If an observer had limited access to a turtle (or provided brief or contradictory comments) such that a turtle would likely have been listed as uninjured rather than injured, the data could have been biased toward lower injury rates than actually occur. This might occur if a turtle was not closely seen by an observer (for example, if a turtle was not brought aboard). If on the other hand, only records with low uncertainty were used, the data could have become biased toward higher injury rates than actually occur. This could have occurred if observers were more likely to include details on injured rather than uninjured turtles.

We assigned all applicable injury categories to each turtle capture. If a turtle had multiple injuries, it was assigned multiple injury codes. Seven injury categories were used to describe the scope of observed injuries. Long cracks included all cracks longer than two inches regardless of whether the cracks were perpendicular or parallel to the mid-line of the turtle. Most long cracks were longitudinal or V-shaped. Other shell injuries included small cracks (<2 in.), chips, scrapes, or scratches to the plastron or carapace. Head and neck injuries ranged from a completely crushed skull, to a missing eye, to abrasions, cuts, and scrapes. Flipper damage included missing appendages as well as cuts and scrapes. The blood and tissue category included any instance when the observer noted blood (from superficial lacerations or from body orifices) or exposed internal tissue. The comatose category only included turtles that were subsequently resuscitated. The "other" category included two turtles that "had trouble diving", one that "had trouble breathing", and one that was not able to "right itself" when swimming.

2.2. Interactions

We assigned a single gear interaction category to each qualifying turtle capture. The interaction categories (first column in Table 1) were based on the most common phrases used by observers to describe where in the gear the turtle had been observed. Because the interaction categories were not mutually exclusive and a turtle was assigned to only a single interaction category, a turtle capture was always assigned to the most specific interaction category. For example, if an observer noted that the turtle was found "in the dredge bag on top of the catch," the record was assigned to the "On top of catch" category because it was the most specific of the applicable categories. It was likely that "in dredge" often meant "in bag", but because "in dredge" could also have meant the turtle was observed in the frame, these two sets of comments were kept separate.

Table 1
Summary of injury and aboard status by gear interaction type

	N	AB	Uncertainty (UNC)					
			Lowest		Intermediate		Highest	
			I	UI	*I*	UI	I	UI
In dredge (generic)	27	20	18	0	1	2	1	5
In bag	11	10	8	0	1	1	0	1
On top of catch	7	7	6	0	1	0	0	0
In sweep or chains	2	1	1	0	0	0	0	1
In frame	4	3	3	0	0	0	0	1
Atop dredge	1	0	0	0	0	0	0	1
Other	22	15	8	0	1	3	3	7
Total	74	56	44	0	4	6	4	16

N = number of observations after records with moderately or severely decomposed turtles have been removed. AB = number of turtles that were brought aboard. The uncertainty categories show the number of records with the lowest, moderate, and highest levels of uncertainty in their injury assessments. *I* = number of injured turtles. UI = number of uninjured turtles. The "other" category included all situations where information about the gear interaction was missing, as well as two instances when observers saw turtles on the surface bump into gear (port stabilizer and main wire).

2.3. Injuries and interactions

It would have been ideal to assess whether injuries occurred on the bottom, in the water column, or on deck; however, observer data only provided enough information to assess whether injuries occurred before or after the turtle was brought aboard the fishing vessel. Interactions that could have led to injuries before the turtle was brought aboard include the turtle getting wedged in the dredge frame, being crushed between the cutting bar and the sea floor, being trapped in the gear and unable to surface, getting harmed while in the dredge bag by the contents of the bag, banging into the side of the vessel as the gear is brought out of the water, and dropping from the gear. Interactions that could have led to injuries after the turtle was brought aboard include falling from the gear onto the deck and being crushed by gear or contents of the dredge bag as it was dumped on deck.

We coded each turtle capture based on whether injuries were likely to occur before or after the gear was brought aboard the fishing vessel. A turtle was considered "brought aboard" after the gear was fully out of the water and hoisted over the deck into position to dump the catch. If the captured turtle was comatose, if injuries were observed but the turtle was not brought aboard, or if the turtle was removed prior to dumping the catch, we surmised it was highly probable that the injury occurred prior to being brought aboard. Examples of observer comments in this category included "turtle removed before dredge dumped", "Crew removed [turtle] before dumping catch", turtle "fell out of starboard dredge before leaving water", and "not brought onboard. . .injuries to the head". If the turtle was stuck (entangled or wedged) in any part of the gear or if the observer comments indicated that care was taken and no injuries were observed when bringing the gear aboard, we surmised it was probable (but not necessarily highly probable) that the injury occurred before being brought aboard. Examples of observer comments in this category included "Captain lowered dredge onto deck and turtle was removed without further damage", "Four fishermen gently lifted out of dredge & laid it on deck", and "caught between crossbars." If an injury was observed to occur aboard, or if the turtle fell onto the deck or the dredge fell onto the turtle, we surmised the injury likely occurred aboard. The single example of a known or likely injury on deck was when an observer noted "dredge dropped on turtle. Cutting bar crushed shell". If the observer data did not include sufficient information to make reasonable conclusions, we determined that it was unknown whether the injury occurred before or after being brought aboard. Most records in this unknown category had no information about the timing of the injury. One record in this unknown category had observer comments that state the "Left side of head smashed by dredge," and "Turtle came up in dredge. Badly injured left side of head crushed. . ."; hence, it is in the unknown category because it is unclear when and where the smashing occurred and whether the observer actually saw the dredge smash the turtle.

2.4. Species composition

To assess the turtle species most likely affected by the scallop dredge fishery, we summed the total number of each captured turtle species for all years based on the observer database ($n = 74$) and genetic analyses ($n = 23$). The comparison of species identification between observer and genetic information was based on the final identification in the observer database, which may have differed from the field identification.

2.5. Stock composition

We used genetic analysis to assess which nesting beach aggregations likely contribute turtles to loggerhead bycatch in the scallop fisheries. Genetic analysis provides the primary information on stock composition because conventional flipper tag data is inadequate. No turtle captured in the scallop dredge fishery to date has had an existing tag, nor have any NEFSC (scallop dredge) observer-applied tags been subsequently found. Scallop trawl data were included because of the NMFS desire (NMFS, 2008) to determine the nesting origin of loggerhead turtles taken in the scallop dredge ($n = 23$) and trawl fisheries ($n = 3$).

Genetic analyses were conducted by the NMFS Southwest Fisheries Science Center, Molecular Ecology Laboratory on twenty-six tissue samples collected from loggerheads incidentally captured in scallop dredge and scallop trawl fisheries between 2002 and 2004. Genomic DNA was isolated from each sample using a Qiagen DNeasy® Tissue extraction kit. Primers LCM15382 and H950g were used to amplify an 800 base pair (bp) fragment of the control region of the mitochondrial genome using polymerase chain reaction (PCR) methodology and standard laboratory techniques (Abreu-Grobois et al., 2006; Bowen et al., 2004). Sequences were obtained using an Applied Biosystems, Inc. genetic analyzer (Models 3100 and 3130). The sequences generated were analyzed using the program Sequencher 3.1 developed by Gene Codes, Inc. Each sequence was reviewed for uncalled and miscalled bases and all variable positions were confirmed by comparing sequences from the forward and reverse strands. Haplotype designation was obtained by comparing generated sequences to the 41 known reference sequences (based on 380 bp) representing published loggerhead haplotypes from Atlantic and Mediterranean nesting populations and foraging aggregations to date (http://accstr.ufl.edu/ccmtdna.html).

Bayesian mixed stock analysis (BAYES, Pella and Masuda, 2001) was used to estimate the contribution of different source nesting stocks to the scallop dredge fishery sample set. Previous analyses have used mitochondrial DNA (mtDNA) haplotype frequency differences to identify eight genetically distinct nesting stocks in the Atlantic: northeast Florida to North Carolina (NEFL-NC), south Florida (SF), northwest Florida (NWFL), Dry Tortugas, Mexico, Greece, Turkey and Brazil (Bass et al., 2004; Bowen et al., 2004; Bolten et al., 1998; Encalada et al., 1998). These eight nesting stocks were considered as potential source populations in the BAYES analysis. Two approaches were used in setting prior parameters for the probability of contribution of each stock with BAYES: an equal contribution from each stock or a weighted contribution by rookery sizes, which may have the best performance in resolving contributions to combined annual samples (Bass et al., 2004). Previous studies indicated that pair-wise comparisons (F_{st} values) between source populations were significantly different (Bass et al., 2004). Due to the small sample size from the scallop fishery,

Table 3
Summary of when injuries likely occur

	HP before	P before	HP after	Unknown
In dredge (generic)	2	6	0	11
In bag	0	4	1	4
On top of catch	1	2	0	4
In sweep or chains	0	0	0	1
In frame	0	2	0	1
Atop dredge	0	0	0	0
Other	3	0	0	6
Total	6	14	1	27

HP before = highly probable that injury occurred before turtle was brought aboard. P before = probable that injury occurred before turtle was brought aboard. HP after = highly probable that the injury occurred after the turtle was brought aboard. Records with highest uncertainty and decomposed turtles have been removed.

Table 2
Summary of the types of injuries reported for all interactions

	Description of injury						
	Long crack	Other shell	Head neck	Flipper	Blood tissue	Coma	Other
In dredge (generic)	9	12	5	8	13	1	2
In bag	5	8	3	5	6	1	1
On top of catch	4	6	4	2	5	1	1
In sweep or chains	1	1	0	1	1	0	0
In frame	2	1	2	1	0	0	0
Atop dredge	0	0	0	0	0	0	0
Other	3	4	0	3	4	1	0
Total	24	32	14	20	29	4	4

Turtles with more than one type of injury are listed in multiple columns. Records with high uncertainty (UNC = High) or moderately or severely decomposed turtles have been removed. Long crack = carapace or plastron cracks longer than two inches. Other shell = small (<2 in.) cracks or chips, scrapes, scratches to plastron or carapace. Head neck = any damage to the head or neck including cuts and scrapes. Flipper = any damage to the front or rear flippers including cuts and scrapes. Blood tissue = bleeding or exposed internal tissue. Coma = comatose and resuscitated. Other = reported problems with ability to swim or dive.

we assumed that haplotype frequencies did not change between years.

2.6. Length frequency

We created size frequency histograms to illustrate the size distribution of turtles incidentally captured in the scallop dredge fishery. When turtles are brought aboard, observers were instructed to record notch to tip length (curvilinear length of the carapace from the nuchal notch to the posterior marginal tip, to the nearest 10th centimeter) and carapace width (curvilinear width of the carapace across the widest part of the shell). We chose 55 cm curved carapace length (CCL) as the break point between the juvenile loggerhead pelagic and benthic stages, and 95 cm CCL as the break point between juvenile and adult loggerheads. These CCL measurements convert to approximately 51 and 89 cm straight carapace length (Teas, 1993). Although there was a large range of sizes and the probability that turtles may move back and forth between behavioral stages (Witzell, 2002), there are several reports suggesting loggerheads generally leave the juvenile pelagic stage around 40–60 cm carapace length (e.g., 46–64 cm CCL, Bjorndal et al., 2000; 52 cm straight carapace length (SCL), Snover et al., 2000). Benthic juveniles are typically associated with near shore feeding habitats (Bowen et al., 2004; Rankin-Baransky et al., 2001), and are generally larger than pelagic, oceanic juveniles and smaller than adults. The average size at maturity for loggerhead turtles calculated from the Cooperative Marine Turtle Tagging Program data is 90.38 cm SCL (NMFS Southeast Fisheries Science Center 2001), but it is recognized that this statistic may be biased large because some turtles may have nested before they were first tagged.

3. Results

3.1. Injuries

The majority of live and fresh dead turtles had low uncertainty regarding their injury assessments (Table 1). Most of the turtles with highly uncertain injury assessments were described as uninjured, and their records lacked specific information about the kind of gear interaction that occurred.

Observers documented injuries in about two-thirds of the live and fresh dead turtles (Table 1). When there was sufficient and explicit information about injury assessments (UNC = Lowest), all turtles were classified as injured. When there was less documented information (i.e., when UNC = Intermediate and Highest), fewer turtles were classified as injured. When records with the highest uncertainty in injury assessments were excluded (Table 2), small (or unknown size) cracks and chips in the carapace or plastron and exposed blood or tissue were the most commonly reported injuries. Longitudinal cracks (>2 in.) in the carapace or plastron and injuries to the flippers were also common. Observers also reported head and neck injuries, and occasionally reported comatose turtles or turtles with other injuries.

3.2. Interactions

When the location of the turtle in the gear was described, it was most frequently reported in the dredge ($n = 27$), in the bag ($n = 11$) or on top of the catch ($n = 7$, Table 1). Only a few turtles were reported in the sweep ($n = 2$), in the dredge frame ($n = 4$), or atop of the dredge ($n = 1$). About 75% of the turtles were brought aboard the fishing vessel. Of the 18 turtles that were not brought aboard, two were bumped by the gear; six were described as being in the dredge and swimming out; two were reported to swim from the gear while it was being rinsed; one was reportedly washed off the bail; one was atop the dredge; one fell from the sweep area; two “fell from” the dredge; one “fell out of” the dredge; and two have little descriptive information.

3.3. Injuries and interactions

Although several different injury and interaction scenarios were described by observers, the most common was an injured turtle, caught in the dredge, and brought aboard the fishing vessel (Table 1). A variety of injuries occurred in each of the gear interaction categories, but no type of injury was uniquely linked with a certain gear interaction (Table 2). The only gear interaction that did not result in an observed turtle injury was “atop dredge”, but this category only had one observation.

The timing of most injuries was unknown, but when observer comments provided information about timing, most injuries likely occurred before the turtle was brought aboard the vessel (Table 3). In approximately half of the cases, observer records did not contain enough information to make assessments about the timing of the injuries. The only instance when observer comments indicated an injury probably occurred aboard was when the observer stated that the cutting bar crushed the turtle when the catch (and dredge) were dumped on deck.

3.4. Species composition

The majority of incidentally captured turtles in the scallop dredge fishery were loggerheads. In addition to 50 loggerheads, the observer program reported one Kemp’s ridley (*Lepidochelys kempii*), one green (*Chelonia mydas*), and 22 unknown species. All 23 turtles with adequate tissue samples for genetic analysis were identified as loggerheads by both the observer program and the genetic analysis. The number of (not decomposed) unidentified turtles observed in

Table 4
Rookery size estimates and distribution of mtDNA haplotypes for Atlantic and Mediterranean loggerhead nesting (source) populations as described in Bass et al. (2004), Bowen et al. (2004), Encalada et al. (1998), and Bolten et al. (1998), including haplotypes found in the sea scallop dredge and trawl fisheries

	Rookery size	Haplotypes (CC-)												
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A14	A20
NEFL-NC	6,200	104	1											
South Florida	67,100	52	45	4		1		3				1	2	1
Northwest Florida	600	38	7	2				2						
Dry Tortugas	217	4	50							2	2			
Mexico	1,800		11	2					1	1	5			
Greece	3,660		78				2				1			
Brazil	2,400				11									
Turkey	1,366		19	13										
Scallop Fisheries	–	13	10					1			1	1		

NEFL-NC = Northeast Florida to North Carolina.

Table 5
Estimated stock mixtures of loggerheads captured in the scallop fishery, based on Bayesian mixed stock analysis and 8 potential source stocks (Bass et al., 2004)

Nesting Stock	Contribution equal for each stock					Contribution weighted by population size				
	Mean	S.D.	Lower quantile	Upper quantile	Weight	Mean	S.D.	Lower quantile	Upper quantile	Weight
Northeast Florida to North Carolina (NEFL-NC)	0.07	0.12	0.00	0.43	0.125	0.03	0.08	0.00	0.30	0.074
South Florida (SF)	0.63	0.25	0.08	0.97	0.125	0.89	0.13	0.51	1.00	0.805
Northwest Florida (NWFL)	0.11	0.18	0.00	0.61	0.125	0.01	0.04	0.00	0.04	0.007
Dry Tortugas	0.07	0.11	0.00	0.38	0.125	0.00	0.03	0.00	0.02	0.003
Mexico	0.06	0.08	0.00	0.28	0.125	0.04	0.06	0.00	0.22	0.022
Greece	0.04	0.08	0.00	0.30	0.125	0.03	0.07	0.00	0.25	0.044
Turkey	0.01	0.03	0.00	0.11	0.125	0.00	0.01	0.00	0.01	0.016
Brazil	0.01	0.01	0.00	0.05	0.125	0.00	0.01	0.00	0.01	0.029

Mean, standard deviation, and lower and upper bounds of 95% probability intervals are shown. Prior parameters of posterior distribution were set to equal contributions from each stock and alternatively set to contribution weighted by population size estimates (Bass et al., 2004).

the scallop dredge fishery has been decreasing (one unidentified out of one observed in 1999, 11 of 13 in 2001, 5 of 22 in 2002, 5 of 24 in 2003, and none unidentified in 2004 and 2005).

3.5. Stock composition

Five loggerhead mtDNA haplotypes were identified among the 26 scallop trawl and dredge fishery samples analyzed. Two of the five haplotypes, CC-A1 and CC-A2, were found in high frequencies among the sample set (13 and 10, respectively), while the remaining three haplotypes (CC-A7, CC-A10, and CC-A11) were identified in only one animal each (Table 4). The two most common haplotypes identified in the sample set also occur in high frequencies in a majority of the Atlantic rookeries (Bass et al., 2004).

Results from the Bayesian mixed stock analysis with priors weighted by population size indicated that the south Florida (SF) nesting stock contributed a majority of the captured turtles (89%, Table 5). Relatively small proportions of the bycatch were attributed to Mexico (4%), NEFL-NC (3%), Greece (3%) and NWFL (1%). When the prior was set to equal contributions from each stock, results differed from the weighted contribution analysis, but still indicated that the SF stock contributed a majority of the captured turtles (63%, Table 5).

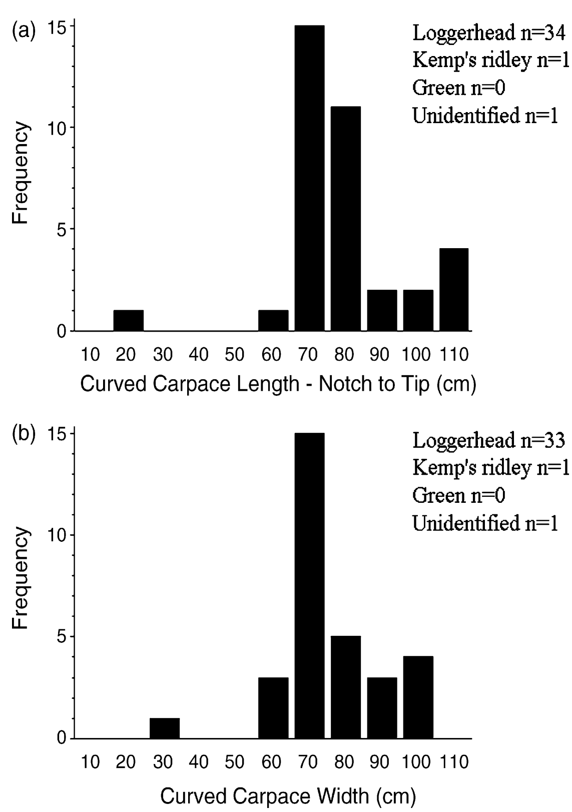

Fig. 3. Size frequency of turtles observed in the scallop dredge fishery. Moderately and heavily decomposed turtles were not included.

3.6. Length frequency

Mean curved carapace length (Fig. 3) of incidentally captured turtles in the scallop fishery was 78.1 (95% confidence limits = 72.9, 83.4); and mean curved carapace width (Fig. 3) was 73.7 (95% confidence limits = 69.0, 78.4). The smallest turtle (24.3 cm curved notch to tip carapace length and 26.0 cm curved carapace width) was the only positively identified Kemp's ridley, and the observer comments contain multiple references to the unusually small size of the turtle. The majority (45 of 74) were the size of benthic juvenile loggerheads. This size class included one turtle that was identified as a green turtle (estimated length of 70 cm). Thirteen turtles were likely adult loggerheads (reported as loggerheads and had carapace lengths ≥95 cm CCL).

4. Discussion

Although the observer dataset has extensive quality control procedures and represented the richest dataset on turtle bycatch in the U.S. sea scallop dredge fishery, uncertainties still exist. For example, we had less confidence in the early species identifications than in more recent identifications. We know that observers occasionally misidentified turtles because field identifications were sometimes changed after NEFOP staff reviewed the photographs (which were not available for all observed turtles). Although the species identifications from genetic analysis matched the species identifications in the observer database, the genetic samples are primarily from recent years and there were photographs of each of the turtles used in the genetic analysis. It is also important to note that observer data represented a subset of the fishery, and rare occurrences may not show up in the database. For example, the NMFS has received an unsubstantiated report of a leatherback turtle being captured in a scallop dredge (DuPaul et al., 2004), but observer records do not document leatherbacks in the scallop dredge fishery.

Using Bayesian analysis techniques, we were able to determine that a majority of loggerheads captured in the scallop dredge and trawl fisheries were likely derived from the south Florida nesting population with relatively small representation from each of the other potential source populations. This finding is generally consistent with reports for loggerheads incidentally captured in the Pamlico-Albemarle Estuarine Complex pound net fisheries and for loggerheads stranded along the eastern coast of the United States (Bass et al., 2004; Rankin-Baransky et al., 2001). Each stock may contribute proportional to the size of its nesting assemblage (Bass et al., 2004; Rankin-Baransky et al., 2001; Bolten et al., 1998), but the geographic proximity of the scallop dredge fishery to the source populations may also influence the contribution from each nesting stock.

Results from the mixed stock analysis (MSA) had wide probability intervals. This illustrates the difficulties of using MSA to precisely assess rookery contributions to a particular mixed population, especially those from smaller stocks when common haplotypes are present in all nesting populations (Bass et al., 2004). Small sample size ($n = 26$) also contributes to the large probability intervals which limit our inferential ability (Bolker et al., 2003). As such, these results should be interpreted with caution until more data are available from additional nesting populations. Use of new primers designed to amplify larger regions of mtDNA and the use of microsatellite analysis should increase our ability to conduct individual assignment analyses to further refine stock structure and better address management needs.

Information on length frequencies and stock structure of bycaught turtles can be combined with existing estimates of the magnitude of turtle bycatch (Murray, 2004a,b, 2005) to assess the impact of the scallop fishery on loggerhead populations. Linking the bycatch to nesting assemblages is especially important as the NMFS considers whether to list loggerheads in the western North Atlantic Ocean as a Distinct Population Segment with endangered status (FR 73 11849).

Current and future scallop dredge gear modifications can now be evaluated in relation to the characteristics of bycaught turtles. Most of the observed interactions resulted in turtles getting caught in the dredge bag, and turtles in this category had multiple documented injuries. Therefore, gear modifications that address interactions resulting in capture in the dredge bag are likely to affect more turtles than modifications that address interactions resulting in turtles getting caught in the sweep, in forward portions of the dredge frame, or atop the dredge. Similarly, because few turtles were comatose, gear modifications that reduce contact injuries are expected to result in a measurable conservation benefit to a larger number of turtles compared with tow time restrictions. Body length and depth measurements should be used to evaluate appropriate spacing of dredge or turtle excluder components.

In sum, the observer data used in this analysis provided valuable information on injuries, interactions, stock composition, and size of turtle bycatch in the scallop dredge fishery. The most commonly described interaction was an injured juvenile loggerhead from the south Florida nesting assemblage, caught in the dredge, and brought aboard the fishing vessel. This information should guide turtle bycatch assessment and mitigation efforts in the scallop dredge fishery.

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